

Technical and Scientific Support for Passive Acoustic Monitoring in the Research Cruise MED09

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LONG-TERM GOALS

Main goal in our R&D program is the development of efficient and reliable tools for marine mammals' acoustic detection, classification, localization and tracking to support research, conservation and mitigation needs. The R&D program on marine mammals began in 1991 based on previous 10 years development of software and hardware for digital sound analysis and was then boosted by joining NURC (1998) in the development of the MMRMP program (formerly SOLMAR). The plan is to continue the improvement of available technologies (towed arrays, autonomous recorders) and to progressively develop semi-automatic tools to assist operators in the classification and tracking of received sources. The ultimate goal is to develop passive acoustics tools for evaluating the presence, distribution and density of marine mammals to support conservation strategies.

OBJECTIVES

The CIBRA tasks on the MED 09 cruise (NRV Alliance; July 27 – September 6, 2009) was to provide and run a Passive Acoustic Monitoring system based on two wide-band low-noise arrays to be towed in parallel at towing speed ranging from 2 to 6 knots. This configuration was designed to provide accurate acoustic detection, classification and tracking of beaked whales in support of distribution mapping and of their localization and tracking for tagging and BRS needs (WHOI Project).

The CIBRA data acquisition system also supported data collection from multiple sources (sonobuoys and other detectors/sensors available on the ship) to evaluate and compare their capabilities, efficiency and reliability. Real time cetacean acoustic detection information was provided by the CIBRA SeaPro and was integrated into the Whale Identification and Logging software (WILD) developed by SPAWAR Systems Center (SSC) Pacific to integrate in real-time navigation, visual sightings and acoustic contacts to support survey, tagging and BRS operations.

Report Documentation Page			Form Approved OMB No. 0704-0188		
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1. REPORT DATE 2009		2. REPORT TYPE		3. DATES COVERED 00-00-2009 to 00-00-2009	
4. TITLE AND SUBTITLE Technical And Scientific Support For Passive Acoustic Monitoring In The Research Cruise MED09			5a. CONTRACT NUMBER		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S)			5d. PROJECT NUMBER		
			5e. TASK NUMBER		
			5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Universitegli Studi di Pavia,Via Taramelli 24,27100 PAVIA ITALY,			8. PERFORMING ORGANIZATION REPORT NUMBER		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSOR/MONITOR'S ACRONYM(S)		
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
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15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 8	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

APPROACH

Thanks to more than 18 years of activity, CIBRA gathered a solid experience in: passive acoustics software and hardware design, making and test; visual and acoustic surveys and techniques; data collection, integration and analysis (acoustic, visual, navigation); marine mammals species identification.

Given this background, we designed and implemented an advanced, reliable, operator based passive acoustic system based on 2 wideband, low-noise arrays and an easy to read, high-resolution real-time visual display. This setup proved to allow the continuous detection and accurate localization of diving vocalizing animals. Although able to get sounds ranging between 300Hz to 90kHz, the system has been focused on Cuvier's beaked whales clicks' range, as the primary goal of the cruise was the detection and tracking of these whales and the discrimination of their signals against the jamming of many other high-frequency impulsive sources (common dolphins, striped dolphins, Risso's dolphins and pilot whales) present in the area. Two skilled operators rotated at the workstation (or were "on alert") during the entire cruise.

Our approach was to develop an user interface to give to an experienced operator all the information (high-resolution real-time spectrographic images of received sounds and a spectrographic spatial display) needed to correctly classify the received signals and to assess the position of the source(s) in relation to the ship. Operators on board were Gianni Pavan (PI) and Claudio Fossati, both with a long experience and with the ability to work on both the software and hardware of the system.

WORK COMPLETED

According to the proposal, CIBRA provided 2 arrays and related equipment. One acted as the main array (Alenia, built in 1993), the second one (named MED09) has been designed and made at CIBRA to match (or exceed) the characteristics (frequency range, self noise, towing speed and depth) of the old one. CIBRA also provided a third array, with slightly different characteristics, intended as a spare unit (Fig. 1).

Unfortunately the MED09 array was lost in the Alboran Sea on 25th of August due to a wrong manouever with a capstain acting as towing point. Since then the spare was used and the two arrays were towed aligned with the one (the spare) with the shorter cable (120m).

The sound analysis workstation developed for previous Sirena cruises was further improved with 8 channels recording capability at 192kHz and 2 channels at 96kHz (for sonobuoys) and suitable storage space (5TB online, 4TB on external drives).

With this system it was possible to provide the same high-resolution spectrographic display capabilities to all systems available on board to facilitate their tuning and performance comparison.

To support twin array operations, a special display was developed to add bearing information to the traditional spectrographic information. The data logging software was modified to transmit detections and, whenever possible, species classification with bearing information, to WILD.

Two experienced operators participated to the whole cruise, assisted by other personnel from NURC to cover the daily monitoring (20h/day, sometimes 24h/day) schedule.



*Figure 1- 1 - CIBRA array, 6cm Ø, 2 sensors, >70 kHz bw, 300m cable
 2 - New array, 4.5cm Ø, 3 sensors, >70 kHz bw, 300m cable
 3 - Spare array, 3.5cm Ø, 2 sensors, >40 kHz bw, 120m cable*

RESULTS

- Survey results

More than 550 hours of wideband acoustic monitoring with two towed arrays (including survey, tracking, and fast transits phases), continuous recording and acoustic classification in 1 minute time slots. More than 100 hours of recording from sonobuoys, either 20kHz and 40kHz bandwidth. Species recorded: dolphins (striped dolphins and common dolphins, difficult to separate), Risso's dolphins, Pilot whales, Sperm whales, Cuvier's beaked whales (more than 10h of recording, including survey and tracking phases). New cues to classify Pilot whales and Risso's dolphins have been found to support the development of automatic classification.

- beaked whales detection with towed arrays

Results obtained in MED09 cruise demonstrate that the detection, localization and tracking of deep diving beaked whales is feasible with sub-surface towed array(s) (20 to 40 meters deep, towing speed ranging from 2 to 6 knots) and with a suitable visual display system able to convey together spectrographic and spatial information (Fig. 2, 4).

In particular, the measure of delayed surface reflections was demonstrated to be an important classification cue indicating that the received sound are generated by a whale foraging at depth in a relatively narrow cone below the receiving hydrophones. This contextual information can easily be

visualized by time-delay estimation techniques. We show that the use of non-acoustic contextual information of a deep diving foraging whale provides a promising approach to improve the classification performance of a passive acoustic detector of beaked whales for both research and mitigation purposes. However, we would underline that the operator experience is still a necessary component of the detection and classification process and the efforts should be addressed in developing tools to aid the operator rather than replacing her/him.

After having developed a display system that conveys spectrographic and spatial information together (Fig. 4), we are now addressed at developing tools to allow the operator to identify on the screen display the signal components on which measures (TDOA – Time Difference Of Arrival, SRD – Surface Reflection Delay) should be made by the software to produce a graphical display of the relative position and movements of the animal(s).

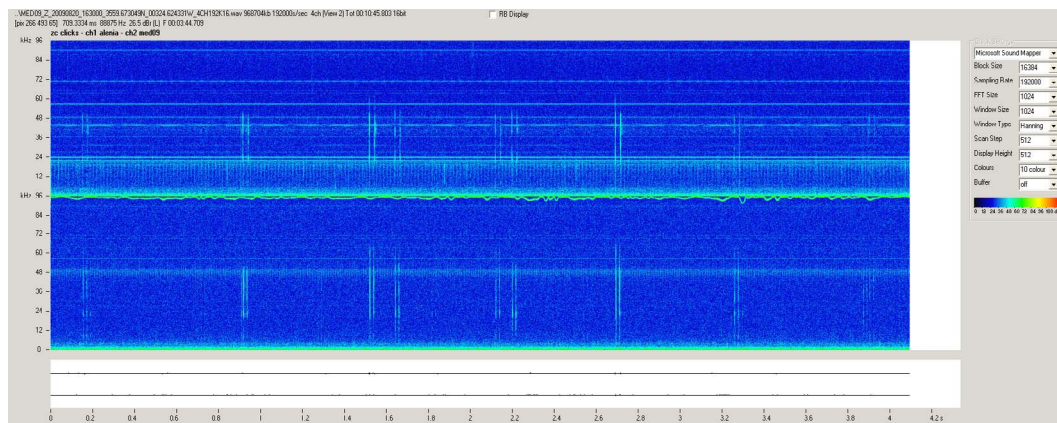


Figure 2 - Spectrogram of two hydrophones. Cuvier's beaked whales clicks recorded at short range; the graph clearly shows the presence of two click series and the surface reflections. Top: Alenia array; bottom: MED09 array.

- beaked whales detection with wideband sonobuoys

Another important result is the demonstration that wideband sonobuoys (40 kHz) can be used to detect and track Cuvier's beaked whales at short range (the exact range is to be estimated in the post-cruise data analysis). Those with GPS send non-audio data on a carrier at 45 kHz and the acoustic bandwidth is sharply limited to 40 kHz. This limits the ability to discriminate different clicks based on the spectral features above 40 kHz, nevertheless, they can be used to track an animal once it can be correctly classified with other wider band systems. Based on MED09 experience, and previous beaked whale detections using shallow hydrophones (Zimmer and Pavan, 2008) the hydrophone depth should be set to 100 or 400ft; figure 3 shows that with the 1000ft setting the surface reflections are much weaker and delayed than with 400ft and this makes more difficult, or impossible, the correct classification of the received signals.

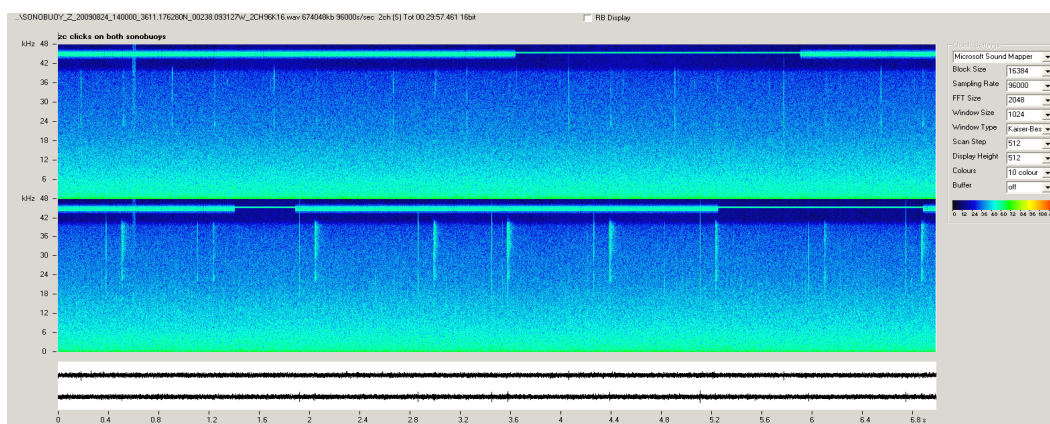


Figure 3 - GPS sonobuoys receiving beaked whales clicks: 1000ft (top) and 400ft.

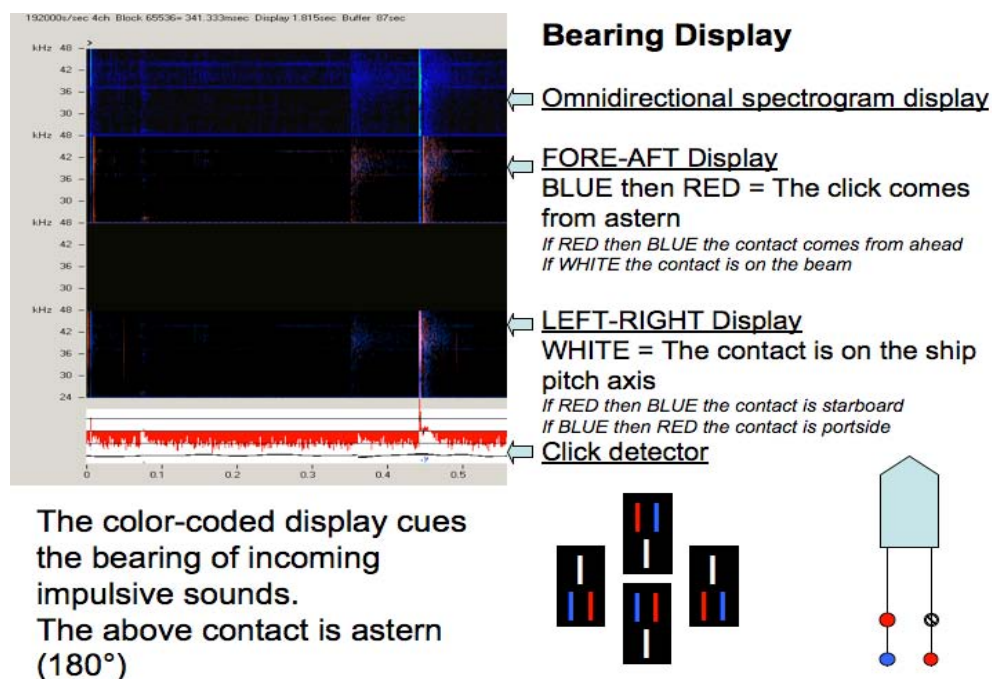


Figure 4 - Spectrographic-bearing display of a dolphin click coming from astern. The display is composed by four strips showing frequencies from 24 to 48kHz; from top: spectrographic display, fore-aft spectrogram display, not used, left-right spectrogram display.

- integration of acoustic data on a real-time GIS display

The real-time integration of multiple information (navigation, tagging boat position, visual sightings – with bearing/range, acoustic detections – with or without bearing/range,) was accomplished using the SSC Pacific WILD system. Acoustic detection information from the CIBRA SeaPro system was transferred to WILD via NMEA strings. The figure 5 shows the integration of visual observation data (red triangles) with acoustic detection data provided by the CIBRA system. Beaked whale presence is indicated by the red circles along the track line (the diameter of the circle indicates the relative signal

strength of the sound) and bearing estimates. This geo-spatial capability was demonstrated to be feasible and a tremendous support to survey, tagging and, potentially, CEE/BRS operations.

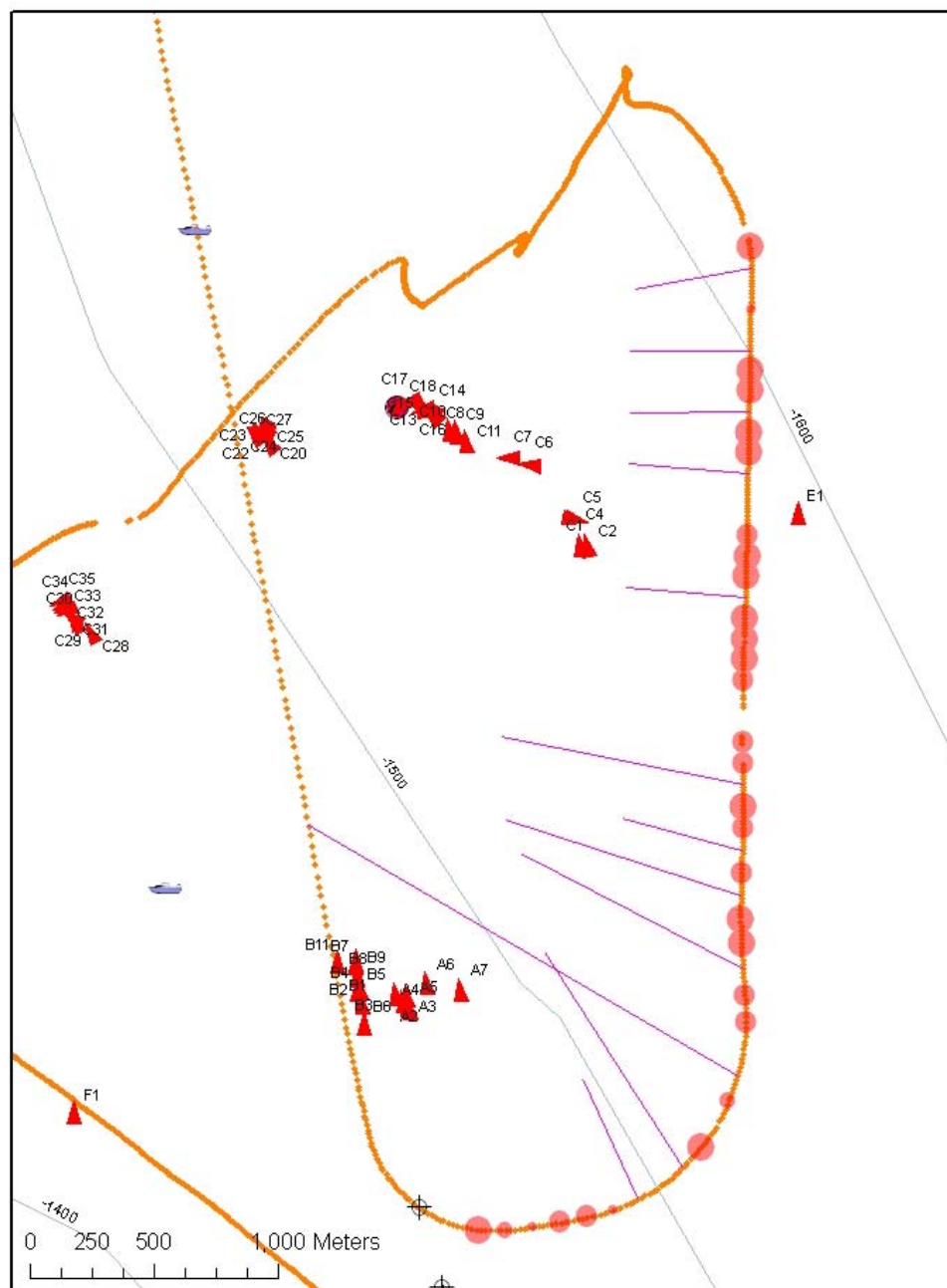


Figure 5 - Tracking of a diving beaked whale that moved underwater from south to north; data displayed using the WILD system.

- high speed acoustic survey with towed arrays

Whilst moving from one survey area to another, we tested the feasibility of acoustic surveys at high speed. We tested our main array up to 10knots with excellent results at least for all the species that can be easily detected at ranges greater than 2 nm. In these conditions it is important to have a long towing

cable, in our case 300m, to keep the sensors deep and far enough. Low speed instead seems to be a key factor in beaked whales' detection probability.

We still have to compare the detection rate at low and high speed; however, the results will be very likely biased by the fact that low speed surveys were concentrated on areas believed or proved to be beaked whales' habitats.

In any case, according to present experience, the detection range of these animals doesn't exceed 1.5 – 2 kilometers. This means that at 4kts, passing on the azimuth of a diving whale, thus in the optimal position, the operator has just 20-30min of time to possibly detect its vocalizations. Giving the intermittent pattern of its acoustic behavior and the long quiet intervals, the slower is the vessel, the greater are the detection chances.

Problems and future improvements

Software components developed to make automatic measures on received clicks (TDOA among hydrophones and surface delay estimation), in the real-time operative context did not worked as expected and, at the very end, the “visual evaluation” of the operator in identifying the correct clicks and assessing the relative position of the source resulted more efficient and reliable. For the future we plan to develop something interactive where the operator “points” to the identified clicks and let the software make the measures.

Work to be done

Post-cruise data analysis will be carried out to verify the beaked whales detections made in real-time and to make all those measures required to assess the position of the animal relative to the ship (TDOA on the hydrophones and surface reflection delays). This will allow to tune the detection model and better assess the detection range and probability. Once all detections will be verified (false positives discarded) it will be possible to produce a map of the detections and assess the number of detected animals. This dataset will be compared with the one produced in Sirena 08 (Alboran Sea only) and included in distribution/density models being developed at NURC within the MMRMP framework.

IMPACT/APPLICATIONS

The system tested in MED09 proved to be the right tool to support tagging operation and BRS studies where it is required to continuously track the animal(s) while they are ensonified. The integration of different detection and tracking systems (towed arrays, tetrahedron developed by NURC, wideband gps-equipped sonobuoys) has also been tested. Further evolution of the systems will provide new tools for mapping their presence and distribution to support the study and conservation of beaked whales and of other marine mammals' species.

TRANSITIONS

The acoustic set (2 towed arrays and spectrographic display with direction indication) designed by CIBRA and used during the MED09 cruise proved to be effective and reliable in tracking “difficult” animals as beaked whales. Its extensive use as the main acoustic investigation tool suggests that it can easily be finalized and consolidated as a tool that could give great support to all the applications that rely on passive acoustics, in particular to Mitigation and Monitoring ops both in civil (e.g. Seismic) and Military (Navy exercises and Sonar tests) environment.

RELATED PROJECTS

The project is within the frame of the NATO URC MMRMP Program and includes on-going cooperation with the SPAWAR Systems Center Pacific and WHOI. Local related projects are the development of autonomous underwater recorders and lightweight towed arrays for mapping the critical habitats of Cuvier's beaked whales in Italian seas. Another related project is LIDO (Listening Into Deep Ocean), funded by EEC, to install two fixed underwater listening stations on the East coast of Sicily connected to the labs by fiber optic cables.

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